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Numerical Methods Incorporated Flows And Transonic Flows

Final Scientific Report

Grant AFOSR-80-0230

Principal Investigator: M. Holt

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Summary of work, July 1980-June 1982

During this period effort was concentrated on two approaches to the solution of the supercritical airfoil problem. The first dealt with the inviscid flow and resulted in the calculation of the symmetrical flow field over ellipses of thickness ratios 0.4 and 0.2 at free stream Mach numbers ranging up to $M_\infty = 0.77$. The second was concerned with flow over a symmetrical circular arc airfoil at high subsonic (supercritical) Mach numbers, including interactions between the outer inviscid flow and the boundary layer, especially in the neighborhood of the shock wave terminating the local supersonic region.

In the first calculation Telenin's method and the method of lines were used to solve the full potential equations in three strages. Elliptic coordinates are used, based on ellipses (ξ = constant) and hypberbolae (η = constant) which are confocal with the given body shape. In the first stage, unknowns are represented by trigonometrical series in η and Telenin's method is applied for the whole ellipse by integrating in directions normal to the body, satisfying boundary conditions on the body and on a confocal ellipse in the far field. In the second stage, this solution is used to generate boundary conditions on a confocal ellipse closer to the body and Telenin's method is applied to provide a more accurate calculation of mixed flow over the forward part of the ellipse, determining the unique flow which smoothly crosses the forward part of the sonic line. This calculation is

extrapolated to provide data on a line traversing the local supersonic region near the aft part of the ellipse. In the third stage the method of lines is applied between the data line and the aft axis of symmetry, interpolating in ξ and integrating in the η direction. This solution is iterated until two intermediate shock points can be determined which are compatible with conditions on the data line and the aft axis of symmetry. Results were presented for ellipses of thickness ratio 0.4 of Mach numbers between 0.65 and 0.68 and ellipses of thickness ratio 0.2 at Mach number 0.77.

In the second calculation the inviscid flow over a circular arc airfoil and the boundary layer flow were matched both in attached and separated regions. The inviscid flow was calculated by Holst's ADI method, using a profile with thickness augmented by the displacement thickness. The boundary layer flow, assumed to be turbulent, was calculated by an improved version of Green's lag entrainment method, due firstly to Le Balleur and secondly to the authors. Results were obtained for a 18% thick circular arc airfoil at supercritical Mach number 0.788 and Reynolds number per chord length of 4×10^6.

In the latter part of the period the method for calculating inviscid flow past an ellipse was extended to apply to flow past a circular arc airfoil.

In Spring 1982, M. Holt was on sabbatical leave, with partial support from the Grant, at the Universite Pierre et Marie Curie, Paris, France. He lectured on the numerical techniques described and also worked on the second edition of his monograph, "Numerical Methods in Fluid Dynamics." He also presented seminars at Grenoble (May) and Aachen (June) on relevant topics.

During the period February-August 1981, Dr. Clive A. J. Fletcher of

the University of Sydney, New South Wales, Australia, visited this Department with partial support from the Grant. He made major advances in numerical techniques, relevant to our current applications, at that time. These culminated in his book, "Computational Galerkin Methods," to be published shortly in the Springer Series in Computational Physics.

Publications

Kon-Ming Li and Maurice Holt, "Supercritical flow past symmetrical airfoils," J. Fluid Mechanics, 114, 399-418, 1982.

L. B. Wigton and M. Holt, "Viscous-Inviscid Interaction in Transonic Flow," AIAA 5th Computational Fluid Dynamics Conference, AIAA-81-1003-CP, 1981.

Y. K. Chuah, "Supercritical flow past a symmetrical bicircular-aric airfoil," M.S. Project Report, Dept. of Mechanical Engineering, University of California, Berkeley, 1982.